Impacts of Ship Emissions on Air Quality in Southern California

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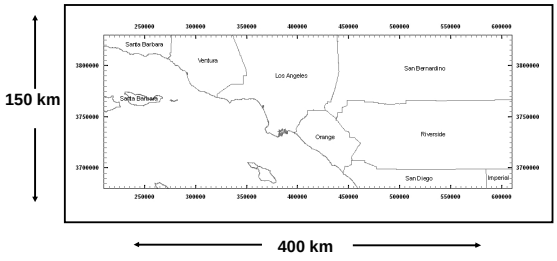
Outline

- Modeling Domain
- CIT Air Quality Model
- Ship Emissions
- Model Configuration
- Air Quality Impacts
- Conclusions, Next Steps

Modeling Domain

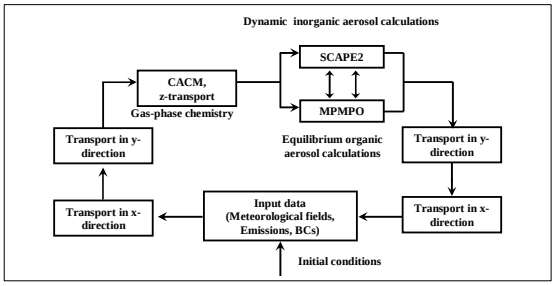


Computational Grid: 80 x 30 horizontal cells, 5x5 km resolution, 5 vertical layers up to 1100 m

CIT Model

- Initially developed at Cal Tech and is currently under continuous development at UCI
- Eularian photochemical grid model
- Incorporates state-of-science modules to model atmospheric processes
- The model is evaluated using data from several field campaigns
- The model is used for many applications to study air quality for the south coast and other regions

Model Components



Numerical Algorithms
QSTSE for advection
PFISLM for aerosol dynamics

CACM Mechanism
191 species:120 fully integrated,
67 pseudo-steady-state, and
4 fixed concentration species

CIT Model Evaluation

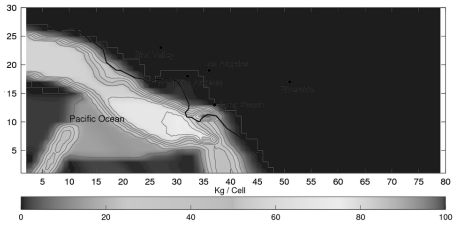
- CIT Model was validated using data from major field experiments.
  - Harley 1993 evaluated the performance for gas-phase species using data from 1987 SCAQS episode.
  - Meng 1998 compared aerosol predictions with observations from 1987 SCAQS episode.
  - Griffin 2002 compared organic aerosol predictions with 1993 field campaign observations.
  - Griffin 2006 applied model components (CACM, MPMPO) to North East region and compared with observations

CIT Model Applications

- CIT Model is extensively applied to South Coast region for air quality studies.
  - Effects of NOx and VOC controls on ambient particulate matter (*Nguyen*, 2002)
  - Modeling of sea-salt chemistry (*Knipping*, 2002)
  - Modeling of renoxification chemistry (*Knipping*, 2002)
  - Modeling the oxidative capacity (*Griffin*, 2004)
  - Calculation of incremental secondary organic aerosol reactivity (*Carreras-Sospedra*, 2005)
  - Distributed power generation studies (*Rodriguez*, 2006)
  - Secondary organic aerosol analysis (*Vutukuru*, 2006)

Ship Emissions

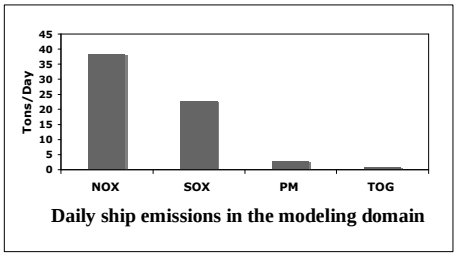
- Spatially-resolved ship emissions for North America are obtained from Prof. Jim Corbett (U Delaware)
- Emissions are formatted to model resolution and size



Daily SOx emissions from ships

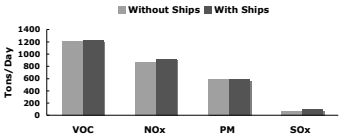
Ship Emissions

- Similarly, emissions of NOx, PM and TOG from ships for the base year 2002 are processed for a summer month
- Hourly emissions are calculated using uniform distribution of emissions throughout the day.

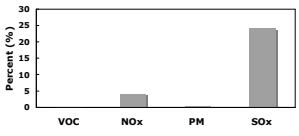


Daily ship emissions in the modeling domain

Ship Emissions



Domain-wide emissions for two cases



Ship emissions as a percentage of total emissions

Ship Emission Speciation

- Emissions from for ROG and PM are speciated
- Chemical mechanisms in air quality models require emissions from individual species
- PM speciation also requires size distribution
- ARB speciation profiles are used to approximate speciation for ship emissions
  - combustion of distillate fuel

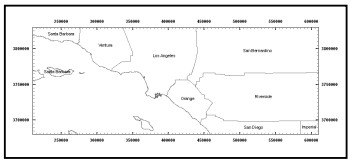
Model Inputs

- Meteorological inputs are used from a 1987 SCAQS campaign.
  - A three-day episode that occurred from August 26 to August 29
  - A comprehensive dataset that is most representative of SoCAB's meteorological conditions
  - Extensively used for air quality studies in the region
- Baseline inventory for the year 1997 is scaled to 2002 levels using county-wide factors.
  - Baseline inventory was used in 2003 AQMP by SCAQMD

Model Configuration

O3: aq, Sf: ~ 0, Nt: ~ 0

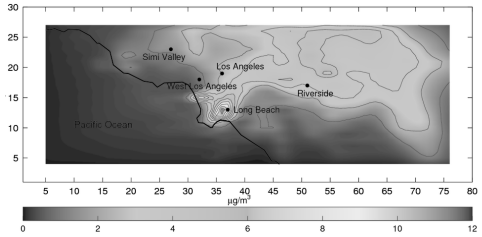
O3: 40 ppb, Sf: ~ 0, Nt: ~ 0



O3: aq, Sf: ~ 0, Nt: ~ 0

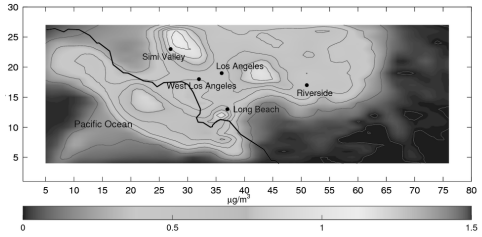
O3: 40 ppb, Sf: ~ 0, Nt: ~ 0

Ambient Sulfates



24-hour average concentration of ambient sulfates without ship emissions

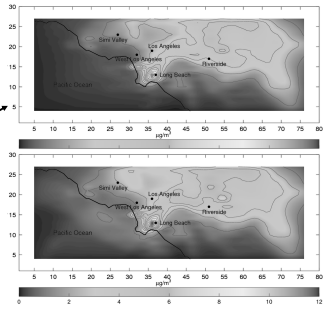
Contribution from Ships



Difference between 24-hour average concentration of ambient sulfates with and without ship emissions

Impact on Ambient Sulfates

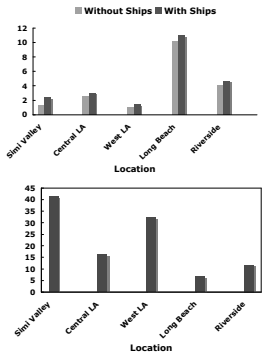
without ships



with ships

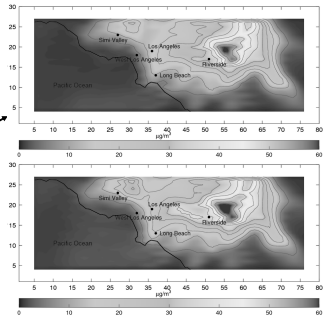
24-hour average concentration of ambient sulfates

Contribution from Ships



Impact on Ambient Nitrates

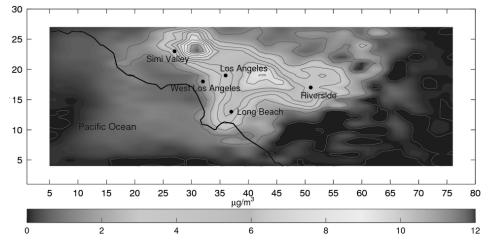
without ships



with ships

24-hour average concentration of ambient nitrates

Contribution from Ships

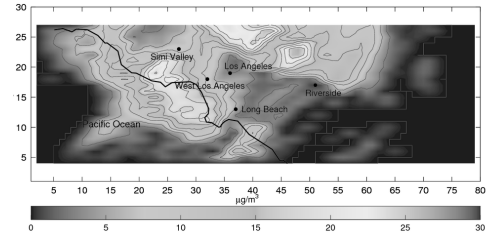


Difference between 24-hour average concentration of ambient nitrates with and without ship emissions

Role of NOx

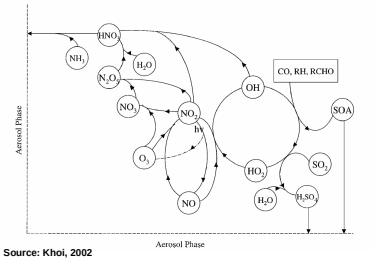
- NOx produces ozone which in turn produces OH radicals
- OH radicals and ozone play a key role in secondary particulate formation
- Relationship between NOx emissions and secondary particulate formation is highly non-linear

Impact on Peak Ozone



Difference between peak ozone concentrations

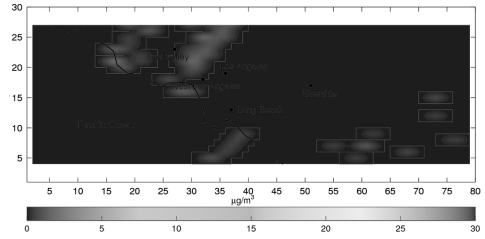
Role of NOx



Source: Khoi, 2002

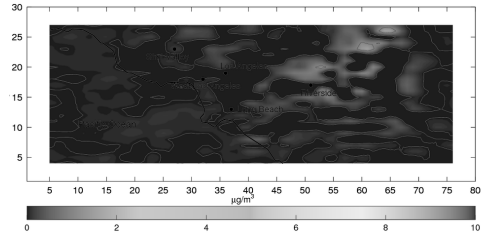
A Sensitivity Experiment:
What is the impact we remove all NOx from ships?

Role of NOx



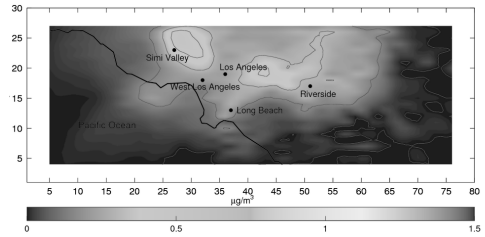
Difference between peak ozone concentrations with zero Nox from ships

Role of NOx



24-hour average concentration of ambient nitrates with zero NOx from ship emissions

Role of NOx



24-hour average concentration of ambient sulfates with zero NOx from ship emissions

Conclusions

- Impact of ship emissions
  - Up to 1.5 μg/m^3 for sulfates and 12 μg/m^3 for nitrates
  - Percentage contribution as high as 45% (Simi Valley area) for ambient sulfates and extends beyond Riverside (15% contribution)
  - Most impact is predicted at locations downwind of urban coastal areas
- NOx from ship emissions contribute to ozone significantly and secondary particulate formation

Next Steps

- Refine assumptions based on discussions at this meeting
- Conduct sensitivity analyses
- Possibly conduct simulations for a future year.

Acknowledgements

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